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**Original Research**

# Comparing the smart model (artificial neural network) and experimental models to assess the watershed runoff of Sarney's dam

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**ABSTRACT:**

Long time ago, various equations were presented by researchers to managethe water resources, which had wide usage in hydrologic sciences. In this paper, by using the observational dates to estimate the runoff, the application of experimental models and artificial neural networks were investigated. For this purpose, runoff amounts were estimated by experimental model and neural smart model, using the physiographic and climatic dates of Qalat Rostam pluviometric and hydrometric stations that were located in Sarney,s dam watershed, and the results were compared to annual runoff amounts. The input parameters included average of annual rainfall, average of annual temperature, minimum and maximum temperature and evaporation values. The results showed that neural smart models had a reasonable accuracy to estimating the runoff by 0.024 Error and 0.98 Correlation. Among the experimental methods used in this research, the Intermediate Complexity Atmospheric Research method showed the best result by 0.52 Error and 0.88 Accuracy. Also by removing the input parameters of artificial neural network one by one, the findings of this paper proved that the most sensitive parameters for this model were rainfall and temperature and the least sensitive parameters were minimum temperature and evaporation. According to the limitation of necessary in formation of the experimental model and high accuracy of smart model, using of neural model was recommended.

**Keywords:**

Runoff, neural network model, ICAR method, Justin method.

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## INTRODUCTION

All over the world, in most watersheds the major source of runoff production is rainfall. It is dependent on various physiographic and climatic features of the watershed, rainfall transformed to the specified runoff amount. Involvement of multiple parameters to transformation of the rainfall to runoff, with high complexity and non-linear relations among the parameters, and input and output of drainage system have caused the runoff and its difficulty. Discharge amount of watershed is an important and principle issue because, the decreases of it can cause financial losses and increases of it can make a floodwater and causes fatality and financial losses. Prediction of river flows for the civil works, river organizing, designing and planning of surface water resources and flood warning system are required for the rainfall runoff analysis. Also, one of the most important and useful issues of water resources management is simulation of river flow for the future period (Ghaffari and Vafakhah, 2013).

Achievement to the flow indexes is essential for the most of construction projects, water resources studies, watershed management projects, etc. One of these indexes is runoff. In researches, the amount of output runoff of rivers was estimated by experimental and mathematical models (Rad, 2006).

In this paper, runoff assessment was done by artificial neural network model and the results was compared to the experimental model findings and hydrometric statistics of Qalat Rostam station and the best model was defined to estimate the runoff value. The amount of input runoff to the Sarney,s dam can be calculated by chosen model with high assurance and due to the increasing of Bandar Abbas population in next years. We can use these results to planning and management of the water resources of Minab,s dam and Sarney,s dam.

Construction of the dam on Sarney river that was located near the Minab city has been started since 2010 and is predicted that the dam will be operated until 2017 to supplying 19 million cubic meter of drinking water requirement of Bandar Abbas population annually, this dam has a reservoir capacity of 90 million cubic meter that will be transferred by the construction of 36 kilometer of water pipe line and preparation of the refinery facilities with the capacity of two cubic meter per second near the Minab city.

### Research purposes

- Assessment of the runoff amount by two experimental models Viz., ICAR and Justin model, and neural network model.
- Determination of the accuracy of ICAR and Justin model and neural network model by comparing it to the hydrometric statistics of the river.
- Selecting the model with reasonable adaptation to estimate the watershed runoff of Sarney,s dam.
- Calibrating the model according to the region.

### Introduction of the used model in this study

### Justin method

In Justin model, in addition to rainfall parameter (P), evaporation variable was effective temperature variable (T), annual discharge (Qj) and calibration of coefficient (Kj) calculated on area (A) and slope (S) of the basin, indirectly.

Qj = Kj(S^0.155*P^2) / (1.8T+ 32 )

S = (Hmax – Hmin) / ( A** 0.5) (Akbarpour *et al.,* 2008).

### ICAR method

In ICAR method, annual runoff (Qi) was calculated by rainfall parameter (P), temperature (T), area of basin (A) and calibration of coefficient (Ki).

Qi = Ki(P^1.44) /( T^1.31*A^0.0613) (Akbarpour *et al.,* 2008).

### Artificial neural networks

Most of the mathematical problems that cause the complex and non-linear equations can be solved easily by defining weights and functions to a multilayer Perceptron. Depending on the method, various functions

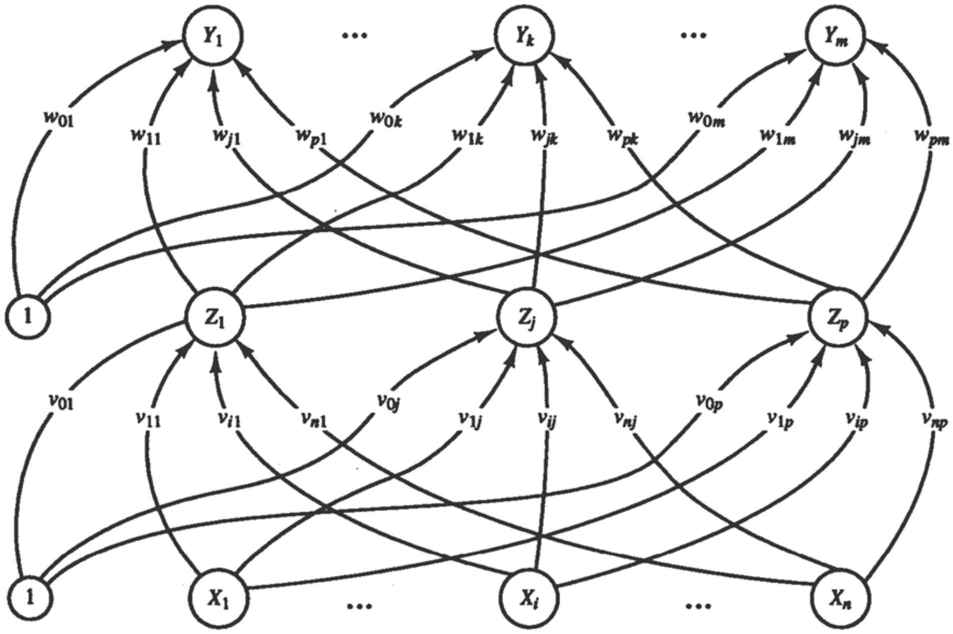


**Figure 1. A Perceptron network**

are used in the neurons. In these networks, three layers are used, an input layer is applied to the entrances of the problem, a hidden layer and an output layer that represent responses of the problem (Araghinejad and Karamoz, 2005).

The nods of input layer were sensitive neurons and the nods of output layer were the responding neurons. The hidden layer had the hidden neurons (Aqil *et al.,* 2010).

Usually training of these networks was done by backwards propagation of errors. Figure 1 showed a type of multilayer Perceptron network.

Two statistics of Root Mean Square Error (RMSE) and coefficient of determination (R2) were used to assess and verify the results. These statistics were calculated by the below given equations:

Formula1. Root Mean Square Error

$$RMSE= \sqrt{\sum_{K=1}^{N} (C_K - M_K)^2 / N}$$

N: The number of data sets

C: Calculated output amount

M: Measured output amount

Formula2. Coefficient of determination

$$R2= \left[\frac{\sum(x-\overline{x})(y-\overline{y})}{\sum(x-\overline{x})^2 \sum(y-\overline{y})^2}\right]^2$$

**Location and general characteristics of the region under study**

Region under study was Sarney,s dam watershed with area over 706 square kilometer that was located 34 kilometer southeast of Minabcity in the main watershed of Persian Gulf and Oman sea on the Sarney river by 90 kilometer length that has been constructed since 2015.

**Hydrometric network**

Dates of 18 stations were taken from water resources office of Ministry of Energy and Hormozgan Regional Water Authority since establishment until now and were used to estimate the discharge.

**2-2- Hydrometric station of Qalat Rostam**

The station,s Zone 38 and latitude and longitude is 275104 and 571914 respectively and is located on the Sarney river. Actually, has statistics given a data from 1986-1994.

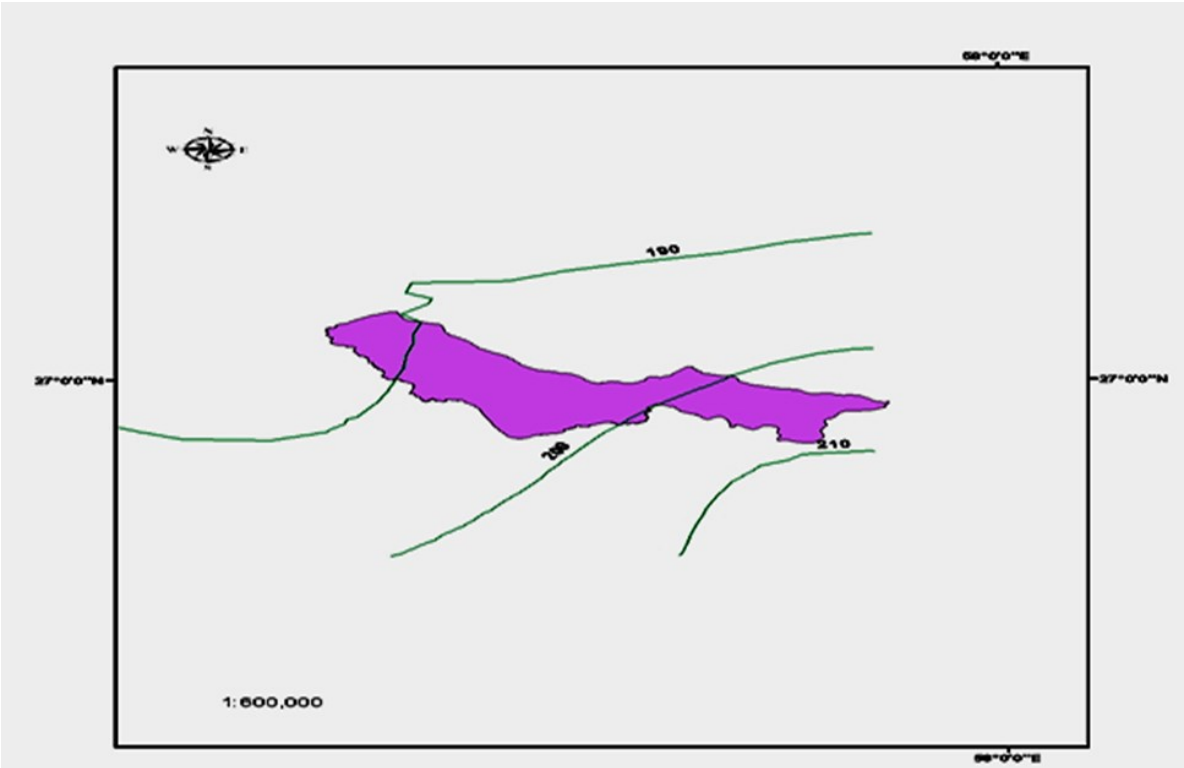


Figure 2. Map of Isolite dam at Sarney

## RESULTS

### Runoff estimation by ICAR method

Table 1. Runoff assessment of Sarney river by ICAR method

| SL. No | Water year (hydrological year) | Averages Annual temperature ($^0$C) | Averages Annual rainfall (cm) | Watershed (km$^2$) | Annual runoff (cm) | Annual runoff (m$^3$/y) | Runoff (m$^3$/s) |
|---|---|---|---|---|---|---|---|
| 1 | 1986-1987 | 33.3 | 18.8 | 706 | 0.62 | 43985192.73 | 1.394761 |
| 2 | 1987-1988 | 35.5 | 17.4 | 706 | 0.51 | 36114315.99 | 1.145177 |
| 3 | 1988-1989 | 34.7 | 18.2 | 706 | 0.56 | 39724255.97 | 1.259648 |
| 4 | 1989-1990 | 35.5 | 16.6 | 706 | 0.48 | 33747695.58 | 1.070132 |
| 5 | 1990-1991 | 34.8 | 6.5 | 706 | 0.13 | 8984078.043 | 0.284883 |
| 6 | 1991-1992 | 33.1 | 24.0 | 706 | 0.89 | 63027364.24 | 1.998585 |
| 7 | 1992-1993 | 34.8 | 23.7 | 706 | 0.82 | 57878317.86 | 1.835309 |
| 8 | 1993-1994 | 35.3 | 10.8 | 706 | 0.26 | 18310768.5 | 0.580631 |

### Justin method

Table 2. Runoff assessment of Sarney river by Justin method

| SL. No | Water year (hydrological year) | Averages Annual temperature ($^0$C) | Averages Annual rainfall (cm) | Watershed (km$^2$) | Average Watershed slope (%) | Coefficient (K) | Runoff (cm) | Runoff (m$^3$/y) | Runoff (m$^3$/s) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1986-1987 | 33.3 | 18.8 | 706 | 1.42 | 0.15 | 0.99 | 70105823.16 | 2.22 |
| 2 | 1987-1988 | 35.5 | 17.4 | 706 | 1.42 | 0.15 | 0.82 | 57573520.08 | 1.83 |
| 3 | 1988-1989 | 34.7 | 18.2 | 706 | 1.42 | 0.15 | 0.91 | 63949584.73 | 2.03 |
| 4 | 1989-1990 | 35.5 | 16.6 | 706 | 1.42 | 0.15 | 0.74 | 52401107.13 | 1.66 |
| 5 | 1990-1991 | 34.8 | 6.5 | 706 | 1.42 | 0.15 | 0.12 | 8141320.942 | 0.26 |
| 6 | 1991-1992 | 33.1 | 24.0 | 706 | 1.42 | 0.15 | 1.62 | 114700348.7 | 3.64 |
| 7 | 1992-1993 | 34.8 | 23.7 | 706 | 1.42 | 0.15 | 1.53 | 108234285.4 | 3.43 |
| 8 | 1993-1994 | 35.3 | 10.8 | 706 | 1.42 | 0.15 | 0.32 | 22264101.23 | 0.71 |

Discharge assessment of Sarney river by Neural network model

**Table 3. Long-term averages of input and output variables in both smart neural structures**

| | Variable | Symbol | Average |
|---|---|---|---|
| Input of network | Rainfall | P mean | 196.4 |
| | Average of temperature | T mean | 27.2 |
| | Minimum of temperature | T min | 20 |
| | Maximum of temperature | T max | 34.4 |
| | Evaporation | T | 2205 |
| Output of network | Volume of annual runoff ($m^3/s$) | R | 26 |

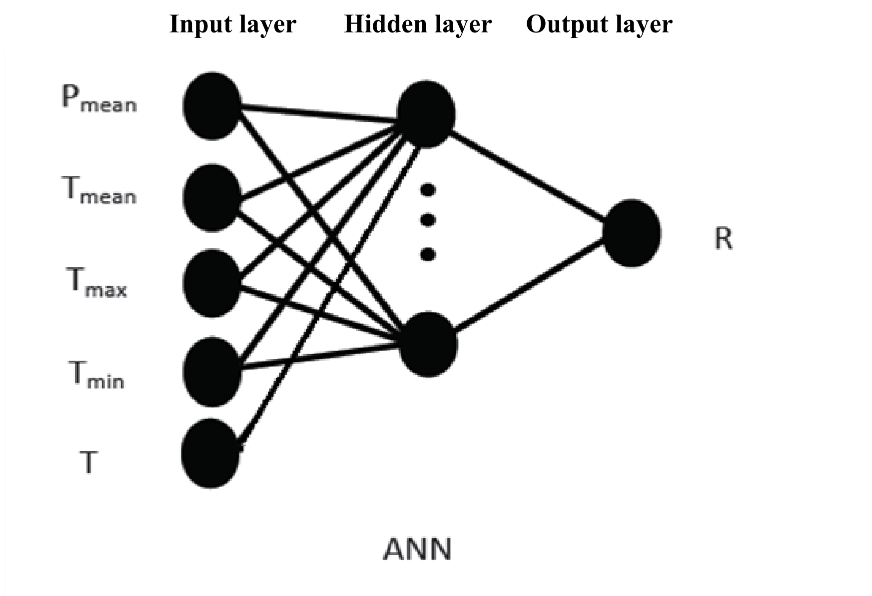


**Figure 3. Schematic of Artificial neural network used in this paper**

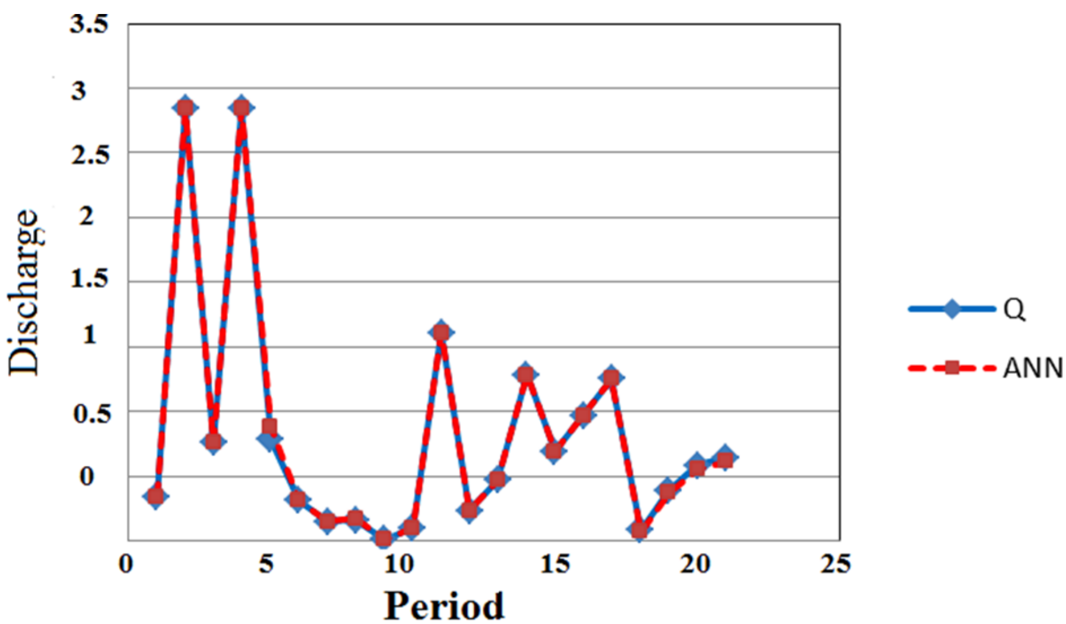


**Figure 4. Comparing estimated runoff amount by the first model of neural network to runoff amount of hydrometric stations**

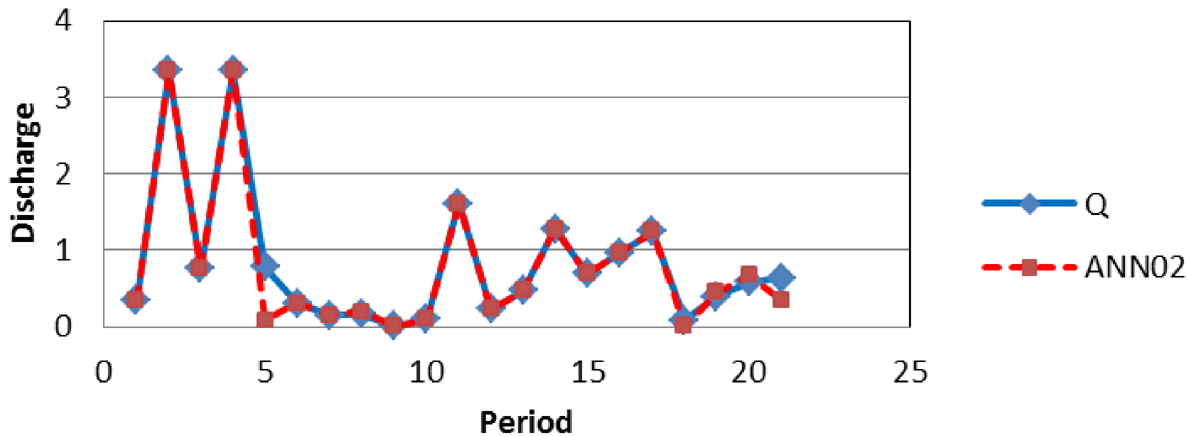


**Figure 5. Comparing estimated runoff amount by the second model of neural network to runoff amount of hydrometric stations**

**Table 4. Comparison of the used methods in this study**

| Model name | R | RMSE | SI |
|---|---|---|---|
| ICAR method | 0.88 | 0.52 | 0.56 |
| Justin method | 0.85 | 1.3 | 1.35 |
| ANN01 | 0.983 | 0.024 | 0.166 |
| ANN02 | 0.965 | 0.029 | 0.193 |

## CONCLUSION

Rainfall to runoff transformation process is so complex and the various components have high interactions. Since the responding of watershed is affected by physiographic and climatic features of runoff, in this paper the estimated amount of runoff was investigated by experimental models and smart neural models (figure 3 and 5).

The discharge dates of Qalat Rostamare available since 1984 until 1994, daily (table 1-4). The Run Test sequences were used to represent the homogeneity of dates. The results showed that the dates are homogenous.

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